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A TECHNIQUE FOR EVALUATING THE ABILITY OF SELECTIONS TO YIELD CONSISTENTLY IN DIFFERENT LOCATIONS OR SEASONS[1]

R. L. PLAISTED AND L. C. PETERSON[2]

The success of a new potato variety depends upon its yielding ability, internal quality, appearance, range of adaptation, and disease and insect resistance. Of these, perhaps the most difficult to assess is the range of adaptation. Prior to release, most selections are placed in yield trials at several locations for two or more seasons. Comparisons are made with the performance of the commercial varieties in production in the area under consideration. In addition to providing an estimate of overall mean yield, this is, in effect, an attempt to describe a variety $\times$ location or variety $\times$ season interaction component for the selection in comparison with some standard. This points out the need to have available a more precise statistical measure of the contribution by a variety or selection to the variety by location or season interaction. Obviously, the final measure of adaptation will depend upon how well the variety is accepted by farmers over a period of years. This statistical measure is an attempt to predict this.

MATERIALS AND METHODS

Data were obtained from yield trials conducted in New York State over a four-year period. Table 1 summarizes the pertinent features of these data. The only varieties common for all four years are Katahdin, Cobbler, and Green Mountain.

The statistical treatment given the data is adapted from a method developed by Horner and Frey (2) to determine the optimum combinations of areas of testing for oat varietal recommendations in Iowa. Briefly, the procedure is as follows:

1. A combined analysis of variance is computed for all varieties at all locations in a given year. If the variety by location mean square is significant, the succeeding steps are followed.
2. Combined analyses of variance are computed for all combinations of pairs of varieties at all locations in a given year. If there are n varieties, there will be $n(n - 1)/_2$ analyses.
3. Observed mean squares are equated to the expected mean squares and solved to obtain an estimate of σ_{VL}^2 from the analysis of each pair of varieties.
4. The arithmetic mean of these estimates is obtained for all pairs of varieties having one common member. There will be $n - 1$ estimates in each mean.

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TABLE 1.—*Characteristics of yield trial data utilized in evaluating the proposed technique.*

Year	Type of Yield Data	Number of Locations	No. of Replications per Location	Number of Entries
1953	U. S. No. 1 and Total	5	4 at 4 locations 5 at 1 location	8
1954	U. S. No. 1	8	4 at 7 locations 3 at 1 location	8
1956	Total	6	4 at 5 locations 3 at 1 location	10
1955	Total	5	4 at 3 locations 3 at 2 locations	12

Let the 1956 data serve as a specific example of the analysis. The overall analysis of variance is given in Table 2.

TABLE 2.—*Combined analysis of variance of all varieties at all locatons in 1956.*

Source	df	ms	F
Total	229		
Locations	5		
Reps in locations	17		
Varieties	9		
Varieties by locations	45	205.956	2.21**
Error	153	93.067	

Since the variety by location interaction is significant at the 1 per cent level, the next step is to compute similar analyses for each possible combination of pairs of varieties. In this case there are 45 such analyses. One example is given in table 3 for the pair Green Mountain-Cobbler. The coefficient of σ_{VL}^2 in the EMS column is dependent upon the number of replications per location. When each location has the same number of replications, then the coefficient is this number. When the number of replications varies with locations, then reference should be made to some statistical text such as *Experimental Design, Theory and Application* by W. T. Federer for computation. The estimate of σ_{VL}^2 is computed from this table in the following manner:

$$\sigma_{VL}^2 = \frac{558.89 - 97.70}{3.83} = 120.42$$

Similarly the estimates of the remaining variance components involving Green Mountain as one member of the pair of varieties are as follows:

Green Mountain	- Katahdin	66.39
" "	- Saco	82.26
" "	- Delus	48.06
" "	- Merrimack	56.37
" "	- Plymouth	171.80
" "	- Early Gem	99.04
" "	- B 926-9	92.07
" "	- B 595-76	62.27

The mean estimate of σ_{VL}^2 involving Green Mountain is computed as follows:

$$\hat{\sigma}_{VL}^2 = \frac{120.42 + 66.39 + \ldots + 62.27}{9} = 88.74$$

TABLE 3.—*Analysis of variance of the pair of varieties, Green Mountain-Cobbler, in 1956 combined over all locations.*

Source	Df	MS	Expected Mean Square
Total	45		
Locations	5		
Reps in locations	17		
Varieties	1		
Varieties x locations	5	558.89	$\sigma^2 + 3.83\ \sigma^2_{VL}$*
Error	17	97.70	σ^2

*It should be noted that the expected mean square for varieties x locations should be $\sigma^2 + 3.83\ (\sigma^2_{VLY} + \sigma^2_{VL})$ since the trial was not repeated over years and since it is not reasonable to assume that the variety x location x years interaction is zero. However the analysis presented here is not invalidated as long as varieties interact with locations in the same way they interact with the location x years interaction. If this is shown not to be true, then two years data of all trials will be needed in order to estimate σ^2_{VL}.

After the mean estimates of σ_{VL}^2 have been obtained, the mean of the other varieties can be obtained. As a check on the accuracy of calculation, this mean should equal, except for errors in rounding, the estimate of σ_{VL}^2 obtained from the analysis of variance of all varieties combined over all locations.

RESULTS AND DISCUSSION

The estimates of the mean variety $\times$ location variance components are given in table 4.

This technique for estimating the relative contribution of each variety to the mean variety $\times$ location interaction component of variance is of merit only if the results of analyses bear out growers' experience concerning the dependability of existing varieties.

TABLE 4.—*Estimates of the relative contribution of several varieties to the mean variety by location interaction component of variance.*

1953			1954		1955		1956	
Variety	U.S. No. 1	Total	U. S. No. 1		Total		Total	
	σ_{VL}^2	σ_{VL}^2	Variety	σ_{VL}^2	Variety	σ_{VL}^2	Variety	σ_{VL}^2
Cobbler	8.3	5.2	Green Mountain	10.3	B 69-16	34.6	Early Gem	12.3
B 441-98	28.3	26.1	B 606-37	15.7	Plymouth	38.7	B 926-9	13.7
Katahdin	29.7	29.0	Katahdin	17.7	Boone	46.0	Cobbler	13.9
Kennebec	30.7	22.6	B 2368-11	18.1	Cobbler	56.2	Katahdin	14.6
Cherokee	54.3	58.1	B 355-35	20.2	B 355-35	59.2	Saco	16.4
Teton	60.6	74.4	B 920-7	30.2	Delus	66.2	Delus	26.3
Keswick	88.8	103.6	B 73-10	41.8	Kennebec	69.9	Merrimack	30.2
Green Mountain	99.9	124.6	Cobbler	45.1	Katahdin	90.6	B 595-76	36.3
					Saco	91.6	Plymouth	42.5
					Merrimack	94.3	Green Mountain	88.7
					B 595-79	96.5		
					Green Mountain	123.0		
Mean	50.1	55.4	Mean	24.9	Mean	72.2	Mean	29.5

In New York State, the area for which analyses are presented, Katahdin has a reputation for being a dependable variety. Green Mountain, on the other hand, is known to vary greatly in yield from location to location and from season to season. The analyses are in accord with this experience in that Green Mountain made the largest contribution to the interaction component in four of five analyses and Katahdin was well below the mean contribution in four of five trials. It is also of interest that Cobbler ranked low in its contribution in the majority of the trials. This may explain in part its persistence as a variety. Whenever Kennebec was present it was below the mean. This evidence is in accord with the description given by Akeley (1), that both Katahdin and Kennebec have wide adaptation.

This method of analysis should be a valuable tool for the breeder to use in making his decision concerning the release of a selection as a named variety. The breeder should first analyze past yield data to select standard varieties for comparison. Thereafter, any selections pending release and the standard varieties should be grown in replicated trials at several locations throughout the area for which the breeder is working. Preferably these trials should be repeated for more than one season. Then, in addition to the usual analysis to compare mean yields, the technique described here should be employed to assess the relative magnitude of the contribution of the selection to the mean variety $\times$ location interaction component of variance, or in other words, to measure its dependability.

The results of this method of analysis may be of value in still another way. It would be wise to select a variety with a low interaction with location and with season for use as a check variety in trials conducted in different locations and years but which for one reason or another cannot be combined in a single analysis of variance. This would increase ones confidence in comparisons between differences between varieties and the check from one trial to another.

Summary

Varieties differ in their ability to produce a dependable crop. In New York experience has shown Katahdin and Cobbler to be favorable in this respect, whereas Green Mountain has a reputation of being variable.

Yield data over locations were analysed in all possible combinations of pairs of varieties. Estimates of the variety $\times$ location component of variance were obtained for each of these analyses. The average of these components for all combinations having a variety in common was defined to be the relative contribution by that variety to the variety $\times$ location interaction. In four of five analyses, Green Mountain had the highest relative contribution to the variety $\times$ location interaction, and Cobbler and Katahdin had a low contribution.

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SOME EFFECTS OF ISOPROPYL N-(3-CHLOROPHENYL) CARBAMATE ON RESPIRATION, WATER UPTAKE AND ION LEAKAGE OF POTATO TISSUE[1]

C. C. Craft and William V. Audia[2]

Isopropyl N-(3-chlorophenyl) carbamate (CIPC) has shown considerable promise as a sprout inhibitor for potato tubers and has given excellent sprout control for periods ranging up to one year at a dosage as low as one-fourth gram per bushel (6, 12, 18). Some knowledge of the physiological effects of this compound on potato tubers, other than its sprout inhibiting properties, is desirable. The work reported in this paper is a study of the effects of CIPC on respiration, water uptake, ion leakage, some chemical transformations requiring oxidative metabolism and the formation of protective barriers by cut potato slices.

The antimitotic effects are considered to be the principal mechanism responsible for the herbicidal properties of the phenyl carbamates (3, 8). In sublethal concentrations CIPC was reported to depress respiration in cotton roots (21) and grass seedlings (1) and to cause a significant increase in reducing and total sugars in corn (14) and soybean plants (13). The application of CIPC to freshly cut surfaces of potato tubers was reported to retard wound healing and to cause loss of fluid and blackening of cut potato surfaces (7).

Materials and Methods

Material: Maine-grown Russet Rural and Katahdin potato tubers stored at 50 or 55° F. were used for most of the experiments reported. Immature Irish Cobbler tubers were also used for a portion of the respiration studies.

Chemicals: Suspensions of CIPC were prepared by dissolving the pure chemical in 1 per cent ethanol and 0.1 per cent Tween 20 and mixing with water. Solutions of 10 mg/liter of CIPC, gibberellic acid (GA) and naphthalene-acetic acid (NAA) were prepared by dissolving the chemicals in warm water without additives. CIPC was also applied by volatilizing weighed amounts of chemical with heat.

Respiration: Direct measurements of oxygen uptake at 25° C. were made by conventional Warburg procedures, using 125-ml. Warburg vessels for the small, whole tubers and 20-ml. vessels without center wells for the potato discs. Uniform slices 0.8 mm. thick were cut from potato tubers with a meat slicer and discs were punched with a 1-cm. cork borer. One gm. of potato tissue in 1.5 ml. of fluid was used routinely for each 20-ml. vessel. In experiments with 2,4-dinitrophenol (DNP), 0.2 ml. of 10^{-3} M DNP, pH 5.5, was added to the medium from a sidearm.

Tetrazolium Reduction: The rate of reduction of 2,3,5-triphenyl tetrazolium chloride by the tissue was estimated by placing freshly cut and washed potato cylinders (approximately 10 mm. x 10 mm.) in a solution of 0.5 per cent tetrazolium salt in 0.05 M phosphate buffer at pH 7.3 and visually estimating the color in the tissue after 1 hour.

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Water Uptake and Ion Leakage: Discs 1.5 mm. thick and 13 mm. in diameter were prepared as previously described and washed for 18 hours in running tap water. The discs were then blotted, weighed and placed in flasks with the test solutions and shaken at a rate of 100 to 120 strokes per minute during the course of the experiment. The test solutions were changed daily and the conductance of these solutions at 25° C. was determined by a Serfass conductivity bridge. The daily change of solutions minimized but did not completely prevent bacterial contamination. After 4 days of shaking, the discs were removed, blotted and weighed and the water uptake was calculated by the increase in fresh weight of the discs.

Optical Density of 325 mμ: Three grams of the discs from each sample were extracted with boiling ethanol and the solution made to 100 ml volume. Aliquots from this ethanolic solution were used for the determination of the optical density at 325 mμ with the Beckman spectrophotometer. This reading was considered a good estimation of the relative amounts of o-dihydroxyphenols present in the tissue.

Estimation of Sugar after Partial Desiccation: Potato discs for the study of sugar accumulation were immersed in the test solutions for 2 hours and, after vacuum infiltration, removed and allowed to dry slowly for 72 hours (4). The discs were then extracted with boiling ethanol and an aliquot used for the estimation of sugar by the method of Roe (17).

Suberin and Periderm: Suberin and periderm were scored in treated potato tissue after 7 days at 60° F. by microscopic observation of sections stained with gentian violet (20).

Results

Respiration: The oxygen uptake of potato tubers dipped in a 0.5 per cent suspension of CIPC was not significantly different from that of untreated tubers during 4 days after treatment (Table 1). Since this concentration of CIPC was demonstrated to control sprouting (6), it appears that CIPC can exert its inhibitory influence on sprout growth without affecting the underlying tissue of the tuber. Work in this laboratory on potato tubers as well as other studies (2, 15) indicate that CIPC is not readily translocated.

Several experiments were conducted in which 1.5 gm. samples of potato discs were placed in one arm of a two-armed 50-ml. tube and fumed by volatilizing 1, 3, 5 and 10 mg. of CIPC from the other arm. The oxygen uptake of these treated discs was not significantly different from that of untreated samples unless injury and discoloration were evident in the discs. Oxygen uptake of discs fumed with 5 and 10 mg. of CIPC respectively, was of a similar magnitude as that of the control samples for at least 4 hours after treatment even though discs treated with these amounts of CIPC were dead after 18 hours.

The oxygen uptake of potato discs incubated in suspensions of CIPC was not significantly different from that of control samples until after the addition of DNP (Table 2). Dinitrophenol is known to cause a marked stimulation in the oxygen uptake of potato discs (19) and work in this laboratory showed that a highly integrated metabolic system is required for a maximum DNP response. The fact that discs treated with CIPC

TABLE 1.—*Oxygen uptake of small potato tubers treated with a 0.5 per cent suspension of isopropyl N-(c-chlorophenyl) carbamate (CIPC)*

Variety	Days after Treatment	Oxygen Uptake at 25° C[1]	
		Untreated	Dipped in 0.5 per cent CIPC
		QO_2 (FW)[2]	
Late-crop	1	9.2	8.5
Russet Rural	2	7.5	7.4
	3	9.8	9.0
	4	9.6	7.9
Mean		9.0	8.2
Early-crop	1	9.1	8.6
Irish Cobbler	2	10.7	8.9
	3	9.8	9.8
	4	8.9	9.6
Mean		9.6	9.2

[1]Means of 2 replications of 8 individual tubers.
[2]Microliters of oxygen uptake per gram of fresh weight per hour.

give a diminished response to DNP indicates that CIPC is causing some type of change even though this effect is not immediately manifested by the rate of oxygen uptake in the samples not treated with dinitrophenol. Of the variety of biological compounds tried, only 2 per cent bovine serum albumin was effective in partially reversing the damage of CIPC. Bovine serum albumin has been reported as a stabilizer for dehydrogenase preparations (16).

Enzymatic Reduction of Tetrazolium Salt: The enzymatic reduction of tetrazolium salt under the proper conditions can be a measure of the relative activity of the dehydrogenase enzymes. Potato cylinders were fumed with 1, 3 and 5 mg. of CIPC and incubated in 0.5 per cent tetrazolium solution at pH 7.3. After 1, 2, and 3 hours these treated cylinders had reduced as much tetrazolium salt as untreated samples. These results indicate that CIPC in sublethal concentrations does not have an immediate or pronounced effect upon the activity of the dehydrogenase enzymes in potato tissue.

Water Uptake, Ion Leakage, and Optical Density at 325 mμ: Naphthaleneacetic acid (NAA) at 10 mg./liter was shown to cause a large increase in the water uptake by potato tissue that was dependent upon oxidative metabolism (5). Naphthaleneacetic acid at 500 mg./liter also was reported to inhibit sprouting in potato tubers (11). Gibberellic acid (GA) was reported to initiate sprouting in potato tubers (10). A comparison of the effects of CIPC with NAA and GA on water uptake, ion leakage and the accumulation of o-dihydroxyphenols in potato discs was made to study the mechanism of action of CIPC (Table 3). The o-dihydroxyphenolic content

was estimated by the optical density of the ethanolic extracts of the potato discs at 325 mμ.

At 10 mg./liter, CIPC and GA showed no significant effect on the water uptake of potato discs when compared with control discs exposed to water alone (Table 3.). Naphthaleneacetic acid caused a significant increase in water uptake when present alone or with GA but showed no effect when

TABLE 2.—*Oxygen uptake before and after the addition of dinitrophenol to Katahdin potato discs (0.8 x 10 mm.) treated with isopropyl N-(3-chlorophenyl) carbamate (CIPC).*

Treatment	Oxygen Uptake at 25° C	
	Before Dinitrophenol	After Dinitrophenol
	Microliters of O_2 Uptake/gm fresh weight x hr.	
Control	57.2	127.4
10^{-5} M CIPC	61.4	116.4
10^{-4} M CIPC	58.2	97.6
10^{-3} M CIPC	51.3	63.8
10^{-3} M CIPC + 2 per cent serum albumin	63.7	121.4
L.S.D. at 5 per cent	N.S.	12.8

TABLE 3.—*The effect of isopropyl N-(3-chlorophenyl) carbamate (CIPC), gibberellic acid (GA) and naphthaleneacetic acid (NAA) on water uptake by potato discs, the conductance of the external solutions. and the optical density of ethanolic extracts of the tissue at 325 mμ.*

Treatment	Increase in Fresh Weight after 4 Days	Conductance	Optical Density at 325 mμ
(Each chemical at 10 mg/liter)	Per cent	*Micromhos* cm²	
Control	11.6	68.6	0.125[1]
CIPC	10.5	136.2	.062
GA	12.2	70.2	.105
NAA	18.3	162.5	.101
CIPC + GA	12.5	138.3	.063
CIPC + NAA	11.2	170.6	.051
GA + NAA	18.0	115.3	.108
CIPC + NAA + GA	12.0	172.1	0.060
L.S.D. at 5 per cent	3.6	32.4	0.017

[1]Optical density of initial sample—0.015.

present with CIPC. The inhibition of NAA-induced water uptake in potato discs by 10 mg./liter (4.68 x 10^{-5} M) CIPC is similar to the inhibition of NAA-induced water uptake by metabolic inhibitors (arsenite, azide, dinitrophenol and fluoracetate) at similar concentrations (5).

Excessive leakage of ions and metabolites from potato discs is an indication of damage to the tissue. CIPC and NAA caused a significant increase in ion leakage from potato tissue when compared with the control sample in water as shown in table 3. GA had no significant effect. The relatively high readings for the CIPC and NAA treatments indicate toxicity. During the first two days of shaking, ion leakage was greater in the CIPC than in the NAA treatment. In view of its other properties, it is difficult to explain this toxic aspect of NAA.

Ion-leakage was highest after the first day of shaking and , except in the NAA treatment, decreased after each successive day until the fifth day when the turbidity of the solutions indicated bacterial growth. Data taken after the fourth day were discarded but the turbidity of the solutions was in direct relation to the conductivity readings.

Ortho-dihydroxyphenolic compounds (principally chlorogenic acid) accumulate in potato discs and this accumulation is dependent upon active metabolism (9). As estimated by the optical density at 325 mμ, CIPC caused a highly significant decrease in the accumulation of o-dihydroxyphenols in potato discs (Table 3). GA and NAA caused a significant decrease in the accumulation of o-dihydroxyphenols but the effect of these compounds was not nearly so striking as that of CIPC.

Sugar Accumulation: CIPC was reported to cause a significant increase in reducing and total sugars in corn (14) and soybean plants (13). Potato discs infiltrated with 10^{-3} or 10^{-4} M CIPC accumulated slightly higher amounts of sugar than untreated samples during partial desiccation. This response is similar to that reported for potato discs treated with metabolic inhibitors and exposed to partial desiccation (4) and does not necessarily indicate that CIPC is directly interfering with carbohydrate metabolism (14). Using potato chip color as an index of sugar accumulation in potato tubers, it was found that CIPC treated tubers responded essentially the same as untreated samples either when stored at 55° F. continuously, or at 40° for 10 weeks and reconditioned at 70° for 5 weeks before frying.

Suberin and Periderm Development: CIPC was reported to interfere with periderm development in cut potato tissue and there were indications that catechal and gibberellic acid partially reversed this inhibition (7). Periderm inhibition in potato slices by CIPC was confirmed in the present work (Table 4). Slices of potato tissue dipped in a suspension of 0.125 per cent CIPC decayed during 7 days at 60° F. This indicated that insufficient suberin and periderm were formed in these slices. The amount of suberin developed by slices dipped in a suspension of 0.05 per cent CIPC was only slightly less than that developed by control samples but significantly less periderm was formed. Despite this periderm inhibition the slices treated with 0.05 per cent CIPC did not decay during 2 weeks at 60°. Gibberellic acid, either alone, or in the presence of the two levels of CIPC had no significant effect upon the development of suberin and periderm.

TABLE 4.—*The effect of isopropyl N-(3-chlorophenyl) carbamate (CIPC) and gibberellic acid (GA) on suberin and periderm development by cut potato slices during 7 days at 60° F.*

Treatment	Suberin[1]	Periderm[1]
Untreated control	4.8	2.0
Additive control	4.6	2.1
0.125 per cent CIPC	Decayed	Decayed
.05 per cent CIPC	4.4	0
.10 per cent GA	5.0	2.1
.125 per cent (CIPC + 0.10 per cent GA)	Decayed	Decayed
0.05 per cent (CIPC + 0.10 per cent GA)	4.3	0
L.S.D. at 5 per cent	0.5	0.3

[1]Rating system from 0 to 5; 0 being none and 5 the largest amount.

DISCUSSION

The results obtained in these varied experiments demonstrate that CIPC in sublethal concentrations elicits toxic responses from potato tissue. The toxic action of CIPC resembles that of a metabolic inhibitor rather than the toxicity resulting from the high concentrations of growth regulators of the substituted phenoxyacetic acid types. CIPC shares the characteristics of many toxic substances and it would appear that it interferes with the surface structure of a cell rather than being specific in point of attack. However, the reason for CIPC being more effective as a sprout inhibitor than other compounds which are as toxic, or even more toxic, remains to be explained.

It is generally agreed that the biological activity of a compound results from a combination of physical properties with chemical reactivity. The physical properties of a molecule generally are responsible for the rate of penetration and movement of a molecule and, hence, often the selectivity, whereas the chemical reactivity is responsible for the toxicity. The low water solubility and the low rate of penetration or translocation of CIPC are probably related to the ability of this compound to selectively inhibit sprouts without significantly modifying the metabolism of the intact tuber. The physical nature of the epidermal layers of tubers and buds quite possibly is important in determining the selective action of CIPC. In addition, it is possible that because of some specialized solubility characteristics (3) CIPC has a selective action on dividing cells and accomplishes its physiological effects both as a toxicant and a narcotic.

SUMMARY

The oxygen uptake of small potato tubers dipped in a 0.5 per cent suspension of isopropyl N-(3-chlorophenyl) carbamate (CIPC) was not significantly different from that of untreated tubers during the 4 days after

treatment. The oxygen uptake of potato discs incubated in dilute suspensions of CIPC was not significantly different from that of control samples until after the addition of 2,4-dinitrophenol. Dinitrophenol caused a large increase in the rate of oxygen uptake of control discs, but only a small increase in the CIPC treated discs. Bovine serum albumin was effective in partially reversing the CIPC inhibition of the dinitrophenol increment in oxygen uptake.

CIPC and gibberellic acid showed no significant effect on the water uptake of potato discs when compared with control discs in water. Naphthaleneacetic acid caused a significant increase in water uptake when present alone or with gibberellic acid but not when present with CIPC. CIPC and naphthaleneacetic acid caused a significant increase in ion leakage from potato tissue when compared with the control samples in water. Gibberellic acid had no significant effect on ion leakage. CIPC caused a significant decrease in the accumulation of o-dihydroxyphenols in potato tissue.

Treatment of freshly cut potato slices with a suspension of 0.125 per cent CIPC resulted in decay during 7 days at 60° F. Under the same conditions 0.05 per cent CIPC caused little or no change in suberin development but a significant decrease in periderm development in potato slices when compared with the control samples. Gibberellic acid had no significant effect on suberin and periderm development.

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INTERNAL BROWNING OF POTATO TUBERS: VARIETAL SUSCEPTIBILITY AS RELATED TO WEATHER AND CULTURAL PRACTICES[1,2]

A. R. Wolcott[3] and N. K. Ellis[4]

In a previous paper (17), descriptions and photographs were presented of four distinct patterns of internal browning found in intimate association in lots and individual specimens of potatoes grown on muck and sandy soils in northern Indiana. These patterns corresponded to symptoms reported for internal brown spot (physiological internal necrosis) (6, 10), heart necrosis (2, 12), corky ringspot (sprain) (1, 5, 9, 13), and canker-type internal rust spot (7, 9, 11). A seasonal sequence in the appearance of the different symptoms was noted. The seasonal appearance of new necrotic symptoms coincided with periods of rising temperature or improved moisture supply. The patterns of internal browning which developed at successive stages of growth appeared to be related to the development age of tuber tissues at the time that injury was incurred.

The purpose of the present paper is to present weather records and quantitative data from field trials that substantiate those observations.

Methods

Twenty standard potato varieties and seedling lines were planted in duplicate plots in 1953 and 1954. Plantings were made on 2 dates in 1953 on each of 2 soils differing greatly in mosture-holding capacity. One was a moderately deep muck (30 to 40 inches) underlain by plastic clay. The other was a shallow, sandy muck (14 to 24 inches), tile-drained and underlain by calcareous sand. In 1954, plantings were made on 2 dates at the sandy muck location only; a high water table (18 to 24 inches) was maintained artificially and a high level of nitrogen fertilization (115 pounds N. per acre compared to 60 pounds in 1953) was supplied.

Tuber counts on 4 hills per plot were made periodically during 1953, and the tubers were cut and examined for necrosis. Similar perodic counts and observations were made at the shallow muck location in 1954 on separate quadruplicate plantings of 6 representative varieties. During both seasons, the date of maturity was estimated on each plot as the time when 75 per cent of vines were dead.

The 25-ft. center rows from 4-row plots were harvested. Random 50-tuber samples from each plot were cut in squares and classified as to severity and type of necrosis. A combined necrotic index for the 4

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types of browning was calculated as a weighted percentage, adjusted for severity of necrosis in the manner of Larson and Albert (10).

Weather Records

Rainfall was recorded daily and temperatures continuously in the plot area. Relative humidity was recorded continuously in the plot area for portions of both seasons. In figure 1, daily maximum and minimum temperatures and daily minimum relative humidty are presented as 7-day moving averages and rainfall as 7-day moving totals. Friedman (6) has pointed out that such average fluctuations represent more significant changes in the environment of the plant than do isolated daily extremes.

Results of Variety Trials

The necrotic indices for 15 potato varieties tested in 1953 and 1954 are presented in table 1. Waseca, Setapa, Katahdin, Irish Cobbler, and Cherokee were consistently resistant to moderately resistant to internal browning in all plantings (7 per cent or less). Ontario and Sebago were consistently susceptible. Russet Rural, Russet Burbank, Pontiac, Redkote, Triumph, Kennebec, and Chippewa showed extreme variability in the degree of injury sustained.

In figure 2 is presented a scatter diagram showing the relationship between necrotic index and maturity date for varieties listed in table 1. In all plantings there was a marked tendency for injury to be greater in the later maturing varieties.

In 1953, most varieties at the shallow muck location matured before September 20. This reflects the maturing influence of recurring drought periods during July and August, and the sharp curtailment of growth which was imposed by the combination of drought and extremely high temperatures at the end of August (Figure 1). Late planting of most varieties resulted in much less vigorous vine growth than did the early planting, and in most varieties injury was less in the later than in the early planting. Corky ringspot was the principal form of injury in Chippewa, Pontiac, Russet Burbank and Triumph.

At the deep muck location, where drought effects on growth were not observed, most varieties did not mature until after September 20. Moderate to severe injury occurred only in varieties which did not mature until October. In these, injury was generally most severe in the later planting, which matured later than the early planting. No corky ringspot was observed in any of the varieties at this location.

At the shallow muck location, where a high water table was maintained in 1954, most varieties did not mature until after the middle of September, and a large proportion of these developed moderate to severe injury. Corky ringspot was the principal form of injury in Triumph, Redkote, Russet Burbank, Sebago, the late planting of Chippewa, and the early planting of Pontiac. Kennebec and Ontario were much more severely injured this year than at the same location the year before, but only about one-third of the injured tubers showed symptoms of corky ringspot. Irish Cobbler and Russet Rural showed no symptoms of corky ringspot in 1953 or 1954.

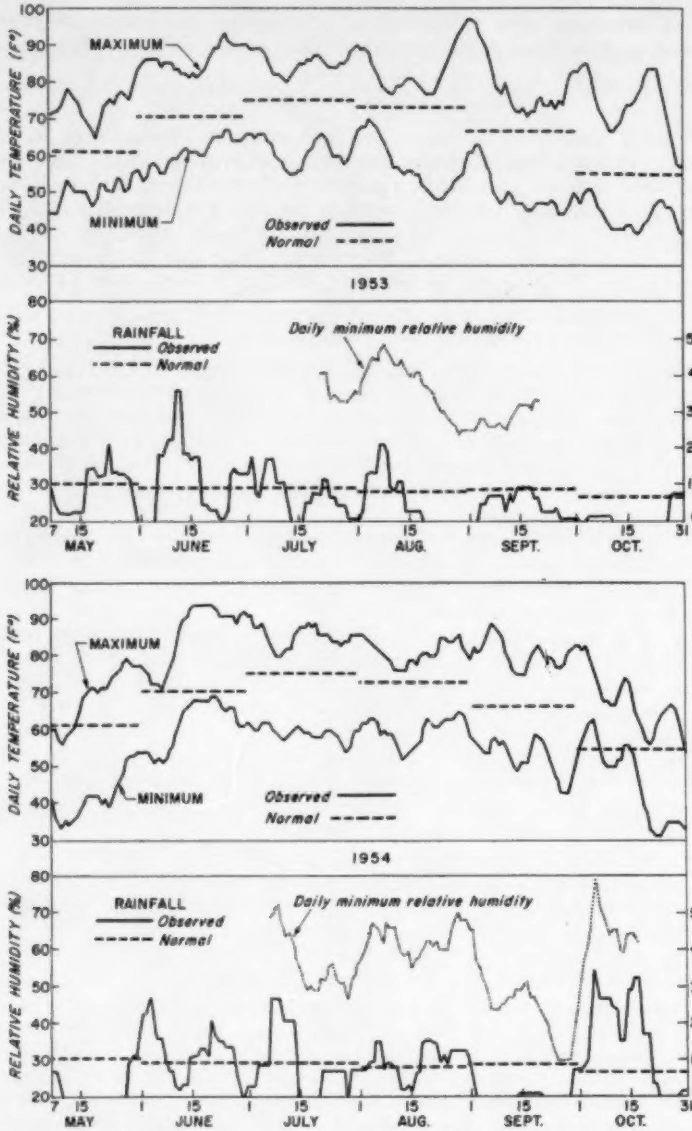

FIGURE 1.—Conditions of temperature, rainfall, and relative humidity during the growing season in 1953 and 1954 in Jasper County, Indiana. The data are presented as the 7-day moving average of the daily maximum and minimum tempreature and daily minimum relative humidity and the 7-day moving total rainfall (6). Monthly normals are shown for comparison (normal rainfall calculated to 7-day moving total basis).

TABLE 1.—*Necrotic indices for potato varieties tested in 1953 and 1954, ranked in order of increasing internal browning injury.*

Varieties with Code Letters, Ranked According to the Average Necrotic Index for All Locations and Dates[1]			Varieties Identified by Code Letters and Ranked According to Necrotic Indices in Tests at Different Locations and Dates[1]							
			May 1 Planting		May 18 Planting		Deep Muck 1953[3]		Shallow Muck 1954[3] (High Water Table)	
Variety	Code	Index	Variety	Index[2]	Variety	Index[2]	Variety	Index[2]	Variety	Index[2]
Waseca	A	3	F	1 d	A	1 b	B	0 c	F	3 c
Setapa	B	3	I	1 d	F	1 b	J	0 c	C	4 c
Katahdin	C	4	A	3 cd	G	1 b	A	1 c	A	6 bc
Cherokee	D	4	C	4 cd	D	2 b	D	1 c	D	6 bc
Irish Cobbler	E	5	E	5 cd	H	2 b	G	1 c	E	6 bc
R. Rural	F	6	B	6 bcd	I	2 b	H	1 c	G	15abc
R. Burbank	G	7	D	7 bcd	L	2 b	K	1 c	H	17abc
Pontiac	H	8	J	8 bcd	B	4 b	I	2 c	M	18abc
Redkote	I	8	L	9 bcd	C	4 b	L	2 c	J	20abc
Triumph	J	9	H	10 bcd	J	4 b	E	3 c	I	21abc
Chippewa	K	10	G	10 bcd	K	4 b	C	5 c	K	22abc
Kennebec	L	14	K	12 bcd	E	6ab	F	15 b	N	30ab
Sebago	M	15	N	14 bc	M	7ab	M	16 b	L	34a
Ontario	N	30	M	17 b	O	9ab	N	18 b	..	
M-804	O	34	O	48a	N	16a	O	40a	..	
Standard Error of Mean				3.11		3.11		1.53		6.90

[1]Necerotic indices calculated as weighted percentages according to Larson and Albert (10). The higher the index, the greater the incidence and/or severity of internal browning injury. An index of 5 is equivalent to 5 per cent severely injured tubers or 15 per cent tubers with mild injury, and is sufficient to exclude a given lot of potatoes from U.S. No. 1 grade.

[2]In a given column, indices denoted by the same letter are not significantly different at 5 per cent (4).

[3]Average for 2 dates of planting. .

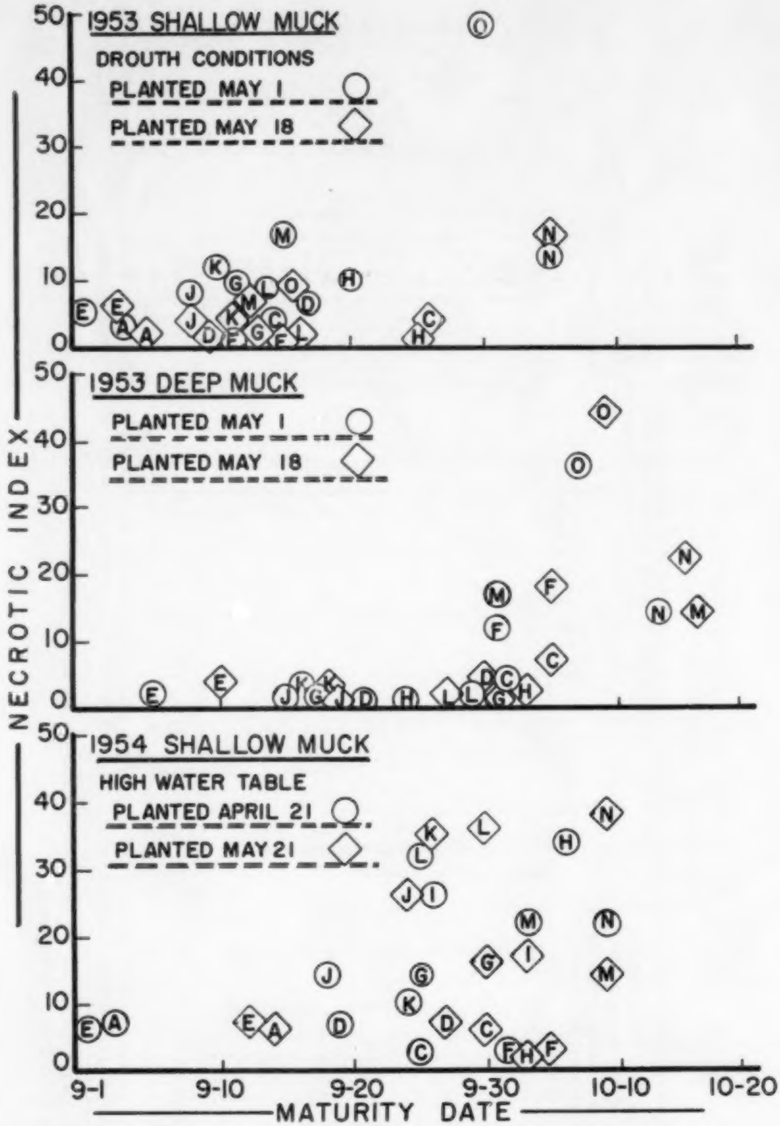

FIGURE 2.—Relationships between necrotic index and maturity date for potato varieties listed in table 1.

Relation of Incidence of Tuber Discoloration to Climatic Sequences and Growth Phenomena

In 1953, the first mild symptoms of diffuse internal brown spot at the shallow muck location were observed during the first few days of August. The climatic sequences preceding this are of interest. The first half of July was marked by a long period of declining temperatures, as shown in figure 1, and no rain fell during the last 10 days of this period. During this period, most varieties at this location stopped initiating new tubers, and tuber enlargement was rapid. There followed a period of generally rising temperatures which continued into the first part of August. This was followed by a period of above-normal rainfall during the first week of August. All varieties responded with a new surge of vigorous terminal vine growth. This coincided with the appearance of the first mild internal brown spot symptoms in a few varieties.

Drought conditions did not develop during July in 1953 at the deep muck location. The initiation of new tubers continued, and rapid tuber enlargement was not observed until late in August.

A second significant climatic sequence in 1953 included the period of declining temperatures during the first 3 weeks of August, followed by a sharp rise to an 8-day period of 90° to 100° F. daily maximums at the end of the month. No rain fell during the latter half of the month. Major damage, at both locations, developed during this period of high temperatures or during the period of near normal rainfall which followed. In a number of varietes which were approaching maturity during this period at the shallow muck location, the principal form of injury was of the corky ringspot type. Acute drought conditions did not develop at the deep muck location during August, and most varieties continued growth beyond the middle of September. On the deep muck, the only forms of browning encountered were the diffuse to blotchy patterns of internal brown spot and the large central lesions of heart necrosis.

Although drought conditions appeared to be significantly related to internal browning in 1953, this was not true in 1954. A high level of soil moisture was maintained in the root zone by a water table maintained continuously at 18 to 24 inches. The combination of high water table with a high level of nitrogen fertilization resulted in much heavier vine growth than in 1953.

Tuberization behavior was very different in 1954 than it was in 1953. This is shown for 6 representative varieties in table 2. The maximum tuber set in 1953 was attained by mid-August and was rather low for all varieties. In 1954, extremely vigorous vine growth was associated with the setting of a very large number of tubers in every variety. Rapid tuber initiation followed a cool period during the early part of July. However, few tubers larger than one-half inch in diameter were found until mid-August. Tuber enlargement was stimulated by the declining temperatures of the first 2 weeks of August. However, most varieties continued to initiate new tubers until the end of the month.

A marked renewal of vigorous terminal vine growth was apparent by the end of August. This was in response to the rising temperatures of the last 2 weeks of the month. Symptoms of diffuse to blotchy internal

TABLE 2.—*Maximum tuber set in 1953 and tubers per hill by date of observation in 1954, compared with necrotic index and percentage of corky ringspot for the same years in early and late plantings of 6 potato varieties on shallow muck, with low water table maintained in 1953 and high water table in 1954.*

Planting and Variety	Maximum Tuber Set 1953[1]	Total Tubers per Hill on Indicated Dates in 1954[2]				Necrotic Index		Corky Ringspot	
		June 20	July 20	Aug. 30	Sept. 22	1953	1954	1953	1954
Early planting (May 1, 1953) (Apr. 21, 1954)									
Cherokee	8	5	34	35	19	7	7	4	3
Chippewa	8	4	50	47	14	12	10	7	0
Katahdin	6	0.5	26	49	12	4	3	0	0
Pontiac	8	0	16	27	16	11	34	9	33
Ontario	8	0.8	33	69	18	15	22	0	11
BE-2335-42	6	0	10	47	14	4	7	0	0
Late planting (May 18, 1953) (May 21, 1954)									
Cherokee	7	0	24	38	15	2	7	0	2
Chippewa	9	0	50	42	14	4	35	2	28
Katahdin	7	0	32	39	9	4	6	2	1
Pontiac	8	0	11	24	14	3	1	2	0
Ontario	9	0	31	50	20	16	39	3	16
BE-2335-42	10	0	0.6	31	18	1	2	0	0

[1]Average of 4 hills per plot and 2 replications.
[2]Average of 4 hills per plot and 4 replications.

brown spot appeared in a number of varieties at this time. Also at this time, numerous small resorbed tuber shells were observed in several varieties.

During the following 3 weeks, extensive resorption of tubers occurred. Sixty per cent of the tubers present on August 30 had disappeared by September 22 (Table 2). Ths reduction in numbers occurred in tubers less than 1½ inches in diameter. During this period, the incidence and severity of internal brown spot symptoms increased, and corky ringspot developed extensively in several of the varieties. In the late planting of Chippewa and in both plantings of Kennebec and Ontario, severe canker type necrosis was also found at harvest time (October 26-30) or during subsequent storage (17).

Climatic conditions during September and early October, 1954 — the period when the more severely injured varieties were approaching maturity — were marked by sharp fluctuations in temperature, wide extremes between day and night temperatures, low relative humidity and almost total lack of rainfall (Figure 1). Lack of soil moisture may be eliminated as a significant environmental factor, since this was adequately maintained by the high water table. The effect of fluctuating temperatures

was reflected in knobby second growth and roughness of the harvested tubers of several varieties.

Discussion

The diffuse to blotchy patterns of internal brown spot are generally considered to be physiological in origin (6, 10). Numerous workers have presented evidence which suggests that the other forms of internal browning encountered in the present studies may be caused by virus or bacterial infection (2, 7, 9, 13). Data presented here and in a previous paper (17) indicate that physiological responses to weather and cultural practices may strongly influence both varietal susceptibility to internal browning and the pattern of injury which develops.

During the two seasons of this study, susceptible varieties and plantings, in a stage of vigorous vine growth and rapid tuber enlargement developed diffuse to blotchy internal brown spot and heart necrosis during periods of rising temperature or of increased rainfall following drought. In susceptible varieties and plantings approaching maturity during periods of fluctuating temperature or moisture during the rapidly shortening day-lengths of September, corky ringspot was the principal form of injury. In 1954, some of these varieties also developed internal rust spot of the canker type. Cankers, however, did not appear until after vines had ripened or tubers had been stored for a time.

Such results may be interpreted on a strictly physiological basis in terms of known photoperiod responses of the potato plant, as modified by genetic constitution, temperature, moisture, and nutrition (3, 8, 14, 15, 16). The climatic sequences found to coincide with the appearance and rapid developmnt of necrotic symptoms parallel those which Werner found conducive to resorption of tubers (14, 15). Extensive resorption of tubers and the development of severe necrosis were observed concurrently during August and September of 1954.

Resorption of water or other tuber constituents to support vigorous vegetative development or respiration and transpiration in the vines has been suggested by others as the primary cause of physiological internal necrosis (internal brown spot) (6, 10). This is probably an over simplification. Resorption of tubers is symptomatic of a shift or reversal of metabolic patterns within the plant.. It appears likely that the primary mechanisms responsible for necrosis should be sought for in enzymatic or nutritional imbalances associated with such shifts in metabolism.

The role of drought and high temperatures in promoting internal browning in potato tubers does not appear to be essentially a direct one. Rather, fluctuations in moisture or temperature act indirectly by regulating the basic metabolism of the plant. Therefore, a period of low moisture supply, by curtailing vegetative growth and promoting tuberization and maturation processes, sets the stage for injurious competitive relationships within the plant when growth processes are stimulated again by a subsequent period of improved moisture supply. A similar situation exists when cool weather is followed by a period of rising temperaures. At certain stages of growth, the simultaneous occurrence of drought and high temperatures may actually exert a protective action by depressing vegetative

extension and promoting rapid maturation. Such an effect appears to have been expressed on the late planting on shallow muck in 1953.

The generally increased incidence and severity of browning in late maturing varieties and plantings suggest that metabolic derangements may be more extreme as processes of maturation are accelerated near the end of the active life of the plant. It is also possible that competition among processes of respiration, growth, storage, and maturation, as influenced by fluctuating temperature and moisture supply, may be exaggerated under short-day conditions. Differences in susceptibility of different varieties to internal browning injury may be related to differences in their basic photoperiod requirements.

Summary

Internal browning injury to potato tubers was more severe in varieties grown in 1954 under conditions of artificially maintained moisture supply than under drought conditions in 1953.

Necrotic symptoms were first observed during, or just after periods, of rising temperature, or of an improved moisture situation following periods of low temperature or drought. Severe internal browning developed concurrently with extensive resorption of tubers during periods of fluctuating temperatures under the shortening daylengths of September. These results may be interpreted in terms of known photoperiod responses of the potato plant, as modified by genetic constitution, temperature, moisture, and nutrition.

The distribution of internal brownspot, heart necrosis, corky ringspot and canker type internal rust spot among varieties and among plantings made on different dates, supports the view that these different patterns of necrosis have a common physiological origin but vary in form and severity with differences in the developmental age of tuber tissues at the time of injury.

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SHELF LIFE OF RAW FRENCH-FRY POTATO STRIPS IN CONSUMER BAGS[1]

R. E. Anderson[2]

The marketing of pre-peeled potatoes is limited largely to hotels, restaurants, hospitals, and similar establishments. Many attempts to establish a retail-market demand for pre-peeled potatoes have been unsuccessful, probably because of their extreme perishability. Reports have shown that pre-peeled potatoes spoil quickly unless stored at or below 40° F. (1, 2, 3, 4). Much of the work has been with 30-pound commercial packs of pre-peeled potatoes or has included only two or three holding temperatures. The shelf line of small consumer packages of 1 pound or less, held at the different temperatures which might occur in retail operations, has not been reported.

This study, during the spring and summer of 1957, determined the effects of temperature and atmosphere within small packages upon the shelf life of pre-peeled raw French-fry potato strips.

Materials and Methods

Lye-peeled potatoes, freshly cut into French-fry strips and treated with a sulfite solution to retard discoloration, were obtained from commercial packers in Washington, D. C. and repacked into perforated and nonperforated 1.5-mil polyethylene bags. Two ⅛-inch holes were made through the center of the perforated bags. Approximately 12 ounces of French-fry strips were placed in each bag. The bags were then heat-sealed and stored at 32, 40, 50, 60, 70, or 85° F. The sample bags from each holding temperature were examined at intervals until the product was judged to be nonsalable.

Shelf life was determined on the basis of color, texture, odor, flavor, and decay by scoring triplicate bags for each examination. Analyses of the package atmosphere for carbon dioxide and oxygen were made on duplicate bags with an Orsat-type gas analyzer. Weight changes of the sample bags were also recorded. The effects of low temperature storage on darkening of the fried potatoes were checked by French frying samples stored at the lower temperatures.

Three varieties of potatoes (Katahdin, Russet Burbank, and White Rose) were included in these experiments involving six different lots of potatoes.

Results and Discussion

The shelf life of pre-peeled potatoes (raw French-fry strips) in either perforated or nonperforated polyethylene bags increases as the storage temperature decreases (Table 1). In both perforated and nonperforated bags the shelf life was less than 1 day at 85° F. and ranged from 3 to 6 days at 50°, whereas at 32° the shelf life ranged from 12 to 15 days in perforated bags and was at least 15 days in nonperforated bags.

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TABLE 1.—*Shelf life of pre-peeled French-fry potato strips stored in polyethylene bags at different temperatures. (Values are means of 6 tests.)*

Storage Temperature	Shelf Life	
	Perforated Bag	Non-perforated Bag
Degrees F.	Days	Days
85	<1	<1
70	1	1
60	1-3	2-3
50	3-6	3-6
40	6-12	9-15
32	12-15	15+

Shelf life was reduced primarily by the development of off-odors (sourness, yeastiness) and off flavors, which at the higher temperatures were accompanied by a very rapid breakdown of the tissue caused by microorganisms. Loss of crisp texture and development of decay were closely associated with the off odors and flavors.

Weight loss during storage was negligible in both the perforated and nonperforated film bags and was not a factor contributing to a reduced shelf life.

The sulfite treatment helped to maintain whiteness but in the perforated bags held at 40° F. marked browning of the potatoes was a factor contributing to a reduced shelf life. In general, the potatoes in nonperforated polyethylene bags maintained an over-all better appearance than did those in the perforated bags.

Samples of French-fry strips that had been stored 8-12 days at 40° or 32° F. did not darken during frying to any greater extent than freshly prepared strips from potatoes that had been stored at 55° F.

The data on package atmospheres in table 2 show the effect of temperature on the carbon dioxide and oxygen levels within the packages. In nonperforated bags at 85° F., the carbon dioxide content rose to 27 per cent after only 1 day of storage and the oxygen concentration dropped below 1 per cent. Even in the perforated bags, a considerable modification of the atmosphere occurred at this temperature. The carbon dioxide concentration averaged 10 per cent and the oxygen concentration 12 per cent. At the lower temperatures the package atmospheres were nearly normal in perforated bags (1 per cent CO_2 and 20 per cent O_2 at 32° F.), whereas in nonperforated bags the atmospheres were altered considerably (5 per cent CO_2 and 8 per cent O_2 at 32° F.). Pre-peeled potatoes in the nonperforated bags maintained a somewhat whiter appearance and had a slightly longer shelf life in several instances than did those in the perforated bags. This may have been caused by the effects of the carbon dioxide which developed in the nonperforated bags, to a better retention of the sulfur dioxide, or to retarded oxidation because of the limited oxygen supply surrounding the product.

TABLE 2.—*Carbon dioxide and oxygen concentrations in polyethylene bags of pre-peeled french-fry potato strips on last day of shelf life. (Values are means of 6 tests.)*

Storage Temperature	Shelf Life[1]	Perforated Bag		Non-perforated Bag	
		CO_2	O_2	CO_2	O_2
Degrees F.	Days	Per cent	Per cent	Per cent	Per cent
85	<1 [2]	10	12	27	0.5
70	1.0	6	17	14	4
60	2.5	5	17	17	2
50	3.5	2	20	9	7
40	11.5	2	20	10	4
32	15+ [3]	1	20	5	8

[1]Average shelf life of both perforated and non-perforated bags.
[2]Analyses performed after 1 day of storage at which time the shelf life had been exceeded.
[3]Analyses performed after 15 days' storage.

SUMMARY

Pre-peeled raw French-fry strips are highly perishable and have a very short shelf life at warm temperatures. An adequate shelf life for retailing can be obtained only through refrigeration at 40° F. or lower. Pre-peeled potatoes packaged in either perforated or nonperforated polyethylene bags kept for less than 1 day at 85° F., from 3 to 6 days at 50°, whereas at 32° they kept from 12 to 15 days in perforated bags, and at least 15 days in nonperforated bags.

Pre-peeled potatoes packaged in nonperforated polyethylene bags maintained slightly better color than did those in perforated polyethylene bags.

Storage of pre-peeled French-fry strips at 40° for 8 to 12 days; or at 32° F. for 15 days did not increase darkening of the cooked product.

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CHEMICAL ELIMINATION OF VOLUNTEER POTATOES[1]

K. H. FERNOW[2]

Within the writer's experience in New York State, potatoes sometimes persist without replanting for periods as long as 20 years. This occurs most frequently where snow accumulates early in the winter because of the presence of woods, hedgerows, fences, or topographical features. The writer has also seen open fields where snow covered the ground before freezing and apparently every tuber left in the field produced a plant the following year. In one instance, such a field carried at least a hundred potato plants per acre for approximately three years after the last potato crop had been harvested.

The ability of volunteer plants to develop evidently depends on the character of the soil as well as on factors previously mentioned. An attempt by the writer, to maintain volunteer potatoes by application of a straw mulch failed in the second winter, apparently caused by soil conditions. Well-drained muckland appears exceptionally well adapted to the maintenance of volunteers. Where the water table is high, however, the tubers may be destroyed during the winter.

For seed growers, the persistence of volunteers creates two problems. If an infested field is replanted with a variety different from that previously grown, the crop becomes mixed as a variety. If the volunteer plants are diseased, there is the additional danger that these will serve as sources of inoculum for the crop. The perpetuation of ring rot by this means from one year to the next is commonly assumed. Personal observations of the writer on the mulched plot previously mentioned support this assumption, since four plants observed the second year showed ring rot symptoms and contained *Corynebacterium sepedonicum* (Spieck. and Kotth.) Skapt. and Burk. Perhaps it is safe to assume that persistence of this disease over a period of several years might occur, although the writer knows of no instances which prove this.

Another disease which is of importance in this connection is leaf roll. If the field in which the volunteers occur is left fallow or planted to some crop other than potatoes, the volunteer plants usually are not protected by parathion sprays against aphid vectors of leaf roll, as is usually done for potato fields intended for seed. If these vectors are abundant, all the volunteer plants may become infected with leaf roll. Later, if potatoes are again planted in these fields, the progeny of the infected plants serve as centers of infection throughout the crop. Even if the seed is planted some distance away, there is a good chance for the transfer of virus by alate aphids. Obviously, the same principles apply in the case of other virus diseases. The volunteers could also serve to perpetuate other injurious organisms.

For the elimination of such volunteers, cultural practices, such as fall plowing, are sometimes resorted to. If this is not effective and if the plants

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In the preparation of this article, helpful suggestions were received from Dr. R. D. Sweet.

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are few and scattered, hand digging may be practiced, but this is laborious and not always effective.

Observations made in the summer of 1957 indicated that 3-amino-1, 2, 4-triazol, hereinafter referred to as amitrol, would destroy the vines and might destroy many of the tubers.

Bodlaender (1) applied amitrol to potato plants for the purpose of preventing new sprout growth in seed potato fields killed early by other chemicals or by mechanical means. He reported that sprout growth was reduced and that tubers harvested from sprayed plants showed a high percentage of rot, and were prevented from germinating.

Rogers (2) studied the action of amitrol and reports that the characteristic chlorosis is caused by the inhibition of the development of plastids. The chemical appears to accumulate in the young leaves and meristems.

Material and Methods

An experiment was carried out in 1958 with amitrol[3] applied to run off with a hand sprayer. The concentration used was 1¼ ounces of actual per gallon (9.3 grams per liter). The potatoes used were of the Chippewa variety planted June 20 with small tubers spaced two feet apart (60 cm).

On July 19, a plot consisting of ten plants from each of two rows was sprayed. Each week thereafter a similar 20-plant plot was sprayed, the last plot being sprayed August 30.

All plots were dug by hand about October 10. Because of a misunderstanding, these plots were not protected with a fungicide and a severe outbreak of blight resulted in the development of blight rot in many tubers. The amitrol produces a rather characteristic breakdown starting at the stem end of the tuber. It was not always possible to differentiate this from late blight rot. Late blight rot was a factor only in the untreated checks and in the plots treated August 30.

On November 5 the tubers were placed in cold storage until December 24, when all the surviving tubers from the amitrol-sprayed plots were planted in the greenhouse as were also 30 tubers from the unsprayed checks. On February 26, two months after planting, 26 of the check tubers had produced plants. The other four were still intact. Of the 42 tubers from the amitrol plots which had survived to be planted, all but seven had rotted. Three of these from the August 30 plot had produced normal plants. The other four, one each from the August 30, August 22, August 16 and August 3 plots were showing a rosette type of sprouting, and it is doubtful whether they would have produced plants. These were accidentally discarded. Therefore, no further observations were possible.

Results

From this experiment it is evident that most, if not all, tubers of unwanted potato plants can be eliminated by spraying with amitrol. It is suggested that, if potato plants occur as single scattered volunteers in fields which are fallow or planted to crops other than potatoes, they can be eliminated by application of amitrol with a hand sprayer. If the unwanted

[3]Under trade name, "Weedazol."

potato plants occur more abundantly and over a wider area, the material might be applied with a weed sprayer or potato sprayer. The most desirable time for spraying would, therefore, seem to be from July 1 to August 20. Since the material destroys plants of many crops by absorption through the leaves, it will be necessary to plan the use of the particular field so as to avoid significant damage to the crop. It is believed that plowing a week after application would not destroy the effectiveness of the treatment. Where scattered plants are to be treated, it may be desirable to use some means for identifying the treated plants. The writer found lampblack at one tablespoon per gallon satisfactory for this purpose.

Summary

Volunteer potato plants, which occur frequently in New York State, constitute a menace to seed production. Their elimination by cultural means is not always practicable. Amitrol was found capable of destroying both plants and new tubers.

Literature Cited

1. Bodlaender, K. B. A. 1958. Inhibition of sprout growth after haulm killing potatoes. European Potato Jour. 1; 3: 28-40.
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COMPARATIVE RATES OF MOVEMENT OF POTATO VIRUS X INTO TUBERS AND EYES OF THREE POTATO VARIETIES[1]

J. P. MacKinnon and James Munro[2]

It has been shown that potato virus X does not move into all tubers of newly infected potato plants (1, 5). Further, it is known that certain potato varieties are less susceptible than others to natural infection with this virus (3, 4).

We have attempted to maintain stocks of the variety Keswick free from virus X for the last five years and have found it difficult to do so. However, stocks of Canso, a variety released at the same time, have been kept free from this virus with relative ease. The variety Katahdin has been grown commercially for 25 years yet some plants can still be found free from infection.

It is not known why tubers of some varieties become infected with this virus more readily than do others. We thought that differences in time of infection and rate of movement of the virus within the plant might result in tubers of one variety becoming infected more rapidly than those of another. We here report the results of a study that was based upon these premises.

Materials and Methods

Isolated small-scale field trials were made in which potato plants were inoculated at different dates and the subsequent progeny indexed; eyes were tested separately so that the percentage of eyes infected could be ascertained. The trials consisted of three plots, each containing three rows six feet apart. One row in each plot was planted with 15 sets of Keswick placed 15 inches apart within the rows. The second row in each plot was planted similarly with Canso and the third with Katahdin. All planted sets were obtained from cut tubers previously eye-indexed and tested on *Gomphrena globosa* L. for freedom from virus X. One week prior to inoculation, leaf samples from all the field plants were tested on *Datura tatula* (L.) Torr. as a check on whether infected tubers had escaped detection in the initial indexing. The numbers of plants of each variety in a plot were then reduced to ten. Inoculations were made by rubbing a top, middle, and bottom leaf on each stem of each plant with sap from infected *D. tatula*. A common field strain of virus X was used.

The trials were carried out in two consecutive years. The 1956 trial was planted on June 11 and harvested on September 20. The plants were inoculated 70, 55, and 30 days before harvest in plots 1, 2 and 3, respectively. Where possible, four tubers were saved from each plant and stored over winter at 4° C. In the spring four eyes from each tuber were planted in the greenhouse. One was taken from the eye end, one from the stem end, and two from opposite sides of each tuber. When the resulting plants

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were between five and eight inches high, they were tested on *G. globosa* for virus X infection.

The 1957 trial was planted on June 12 and harvested on September 25. The procedure was similar to that carried out in 1956, but the periods between inoculations and harvesting were 55, 35, and 15 days, respectively, for plots 1, 2, and 3. In this trial, all plants from the harvested tubers that gave a negative reaction on *G. globosa* were tested a second time.

Results and Discussion

The results of two year's trials showed that virus X reached all tubers in the three varieties and nearly all the eyes in these tubers when the time from inoculation to harvest was 55 days or more.

When the time for virus movement was 30 days in the 1956 trial, the percentage of tuber infection in Keswick, Canso ,and Katahdin was 100, 82 and 78, respectively. For this period, the percentage of eye infection in infected tubers was quite similar to that of the 35-day period of 1957 (Table 1).

In the 1957 test, when the interval between inoculation and harvest was either 35 or 15 days, a larger percentage of infected tubers and eyes was found in Keswick than in either Canso or Katahdin. Katahdin had the least number of infected tubers and eyes in the three varieties tested as revealed in table 1.

The number of partially infected tubers in the three varieties increased as the time for virus movement from leaves to tubers decreased. This indicates that little, if any, movement of virus took place within the tubers during storage.

Table 2 shows the number of times virus X was found in eyes from different regions of tubers not wholly infected. The virus was found in eyes from the eye end more frequently than in eyes from the stem end or sides of Keswick tubers, but no differences were found in either Canso or Katahdin. Beemster (2) found in some European varieties that eyes from the eye end were more likely to be infected with virus X than eyes from the basal end. Our results suggest that in partially infected tubers, varieties may differ as to the region in which eyes are most often infected, although the number of tubers in these tests is too small to draw definite conclusions.

When 90 field plants of each variety (grown from indexed tubers) were tested before inoculation, it was found that eight Keswick and three Canso were already infected. These were removed together with some non-infected plants when the number of each variety in the plots was reduced to ten. As there was little chance of contamination, it was most likely that either the indicator plants had failed to show the presence of the virus in the eyes tested or that other eyes in these same tubers were infected. During the course of this work we found some tubers partially infected, particularly those from plants infected late in the season. We were therefore not surprised to find this to be so with some of the tubers that were used for planting the trial plots.

We also found that when plants which had given a negative reaction on *G. globosa* were retested a week later, an occasional plant was found to be infected. This may have been due to a delayed movement of virus

TABLE 1.—*Percentage of infected tubers harvested from plants inoculated with potato virus X in 1957, and percentage of infected eyes in all tested tubers.*

Varieties Days from Inoculation to Harvest	Keswick		Canso		Katahdin	
	35	15	35	15	35	15
Per cent tuber infection (40 tested)	100	81	93	35	69	15
Per cent eye infection (160 tested)	99	70	86	16	60	10

TABLE 2.—*Distribution of infected eyes in tubers not wholly infected with potato virus X in 1957.*

Variety	No. of Partially Infected Tubers	Region of Tubers from Where Eye Was Tested		
		Eye End	Stem End	Sides[1]
Keswick	9	7	3	5, 3
Canso	15	6	10	8, 6
Katahdin	12	6	7	6, 4

[1]Two eyes were tested from opposite sides of each tuber.

from the planted eye to the foliage of small plants or to the concentration of virus in the expressed sap. Nevertheless, our experience has shown that the inoculation of sap to *G. globosa* is as accurate a method for the detection of virus X as any other method presently in use. But it should not be assumed that when one eye from a tuber is shown to be free from virus X the other eyes in that tuber are likewise free.

SUMMARY

When Keswick, Canso, and Katahdin plants were inoculated with potato virus X 35 days or less before harvest, the virus moved into more tubers of Keswick than of Canso or Katahdin. The least number of infected tubers was found in Katahdin. The number of tubers not wholly infected increased in the three varieties as the time from inoculation to harvest decreased. In partially infected tubers of Keswick, virus X was found in eyes from the eye end more frequently than in eyes from the stem end or sides, but in Canso and Katahdin the location of an eye had no apparent effect on whether or not an eye become infected. Infected and non-infected tubers were found under some plants in each of the three varieties. Little, if any, movement of virus had taken place within tubers during storage.

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COMMITTEE REPORTS (Continued)

REPORT OF COMMITTEE ON THE GENETICS AND CYTOLOGY OF TUBER-BEARING *SOLANUMS*

An appreciable amount of information has now accumulated on the genetics and cytology of the genus *Solanum*. However, few potato breeding programs have had the advantage of well organized genetic and cytological support. During the past ten years, the potato breeders have been urging the necessity for additional basic information if solutions are to be found to some important breeding problems. Probably as a direct response to this need of the breeders, a number of projects on the genetics, cytology and physiology of "potatoes" have been organized and the trend is gaining momentum. To help in co-ordinating this work, the Potato Association of America has formed a standing committee on the genetics and cytology of tuber-bearing *Solanums*, whose aims will be: [1] to provide a forum for the discussion of problems and a clearing house for newly acquired information; [2] to provide a vehicle for the rapid exchange of valuable germ plasm; [3] to give the potato breeders information, methods and materials to aid them with the problems of potato improvement.

In this, its first report, the committee has decided to publish a list of the projects in genetics and cytology known to be currently underway in North America. While the list is probably not complete, the committee believes it would be useful to publish this information at the present time.

The following projects have been brought to the attention of the committee:

Canada — C.D.A. Research Station, Fredericton, N. B.

The inheritance of immunity to Solanum virus Y in *Solanum stoloniferum*. D. A. Young.

The inheritance of resistance to Solanum virus S. D. A. Young and R. H. Bagnall.

The inheritance of resistance to higher races of *Phytophthora infestans*. L. A. Dionne, K. M. Graham, W. A. Hodgson, P. B. Spicer.

The transfer of scab resistance from *Solanum chacoense* to early types of *S. tuberosum*. L. A. Dionne, C. H. Lawrence, P. B. Spicer.

The transfer of immunity to *Solanum* virus Y from *S. stoloniferum* to *S. tuberosum*. L. A. Dionne, J. Munro, P. B. Spicer.

Studies of incompatibility between the Mexican stellate flowered series of *Solanum* and the *tuberosa*. L. A. Dionne, P. B. Spicer, K. M. Graham.

Studies of dormancy in newly harvested seeds of the tuber bearing species of *Solanum*. P. B. Spicer and L. A. Dionne.

Iowa — In cooperation with U.S.D.A. Crops Research Division, Beltsville, Maryland.

Studies on the effect of homozygosity on the loss of vigor in inbreds of *S. tuberosum*.

The isolation of superior inbred parental lines of *S. tuberosum*.

Studies on the inheritance of immunity to *Solanum* virus X from combinations of certain susceptible parents.

Developing *Phytophthora* resistant potatoes having resistance genes 1, 2, 3, and 4.

The isolation of haploid (2n) *S. tuberosum* derivatives.

A. E. Kehr, J. C. Horton, Lin Sanford, E. T. Hibbs, *et al.*

Minnesota — University of Minnesota, St. Paul, Minnesota.

The development of superior inbred parents as sources of disease resistance combined with earliness, fertility and quality.

The use of wild *Solanum* species as sources of disease resistance. F. I. Lauer.

New York — Cornell University, Ithaca, New York.

Studies on the rate of approach to homozygosity in *S. tuberosum* through recently devised statistical procedures.

The inheritance of resistance to Golden nematode and "yellow stigma" from selections of *Solanum vernei*. R. L. Plaisted.

Pennsylvania — Pennsylvania State University, University Park, Pa.

Studies of the genetic and cytological barriers isolating diploid species of *Solanum*.

Studies of meiosis in clones of *S. tuberosum*.

Studies on the use of stainability as a criterion of pollen germinability. P. Grun.

U.S.D.A. — Crops Research Division, Beltsville, Maryland.

Studies of crossability between diploid species of Solanum [1] Incompatibility mechanisms [2] Studies of meiosis in the species hybrids. R. W. Buck, Jr.

Wisconsin — University of Wisconsin, Madison, Wisconsin. (Cooperative with the Agricultural Research Service, U.S.D.A.)

Studies of haploidy in *Solanum tuberosum*: [1] Methods of obtaining haploid individuals. [2] Factors affecting occurrence of haploids. [3] Use of haploids in breeding and genetics research. R. W. Hougas, S. J. Peloquin, R. W. Ross.

Interspecific crossability among the tuber-bearing *Solanum* species. D. C. Cooper, G. H. Rieman, R. W. Hougas, S. J. Peloquin.

The development of techniques for increasing fruit and seed set following difficult crosses of *Solanum* species. S. J. Peloquin, R. W. Hougas.

The development of techniques for overcoming self incompatibility in diploid species of *Solanum*. S. J. Peloquin, R. W. Hougas.

The embryo culture of interspecific *Solanum* hybrids. D. C. Cooper, S. J. Peloquin, R. W. Hougas.

A list of recent papers by North American researchers covering pertinent aspects of this work is appended:

1. Beamish, K.I. 1955. Seed failure following hybridization between the hexaploid *Solanum demissum* and four diploid *Solanum* species. Amer. Jour. Bot. 42: 297-304.
2. ————, D. C. Cooper, and R. W. Hougas. 1957. Induced tetraploid *Solanum* species and species hybrids; meiosis and use in breeding. Amer. Jour. Bot. 44: 305-310.
3. Bienz, Darrel R. 1958. The influence of environmental factors and pollinating techniques on the success of potato pollination in the greenhouse. Amer. Potato Jour. 35: 377-385.
4. Cooper, D. C. and G. H. Rieman. 1958. Diploid plants in a seedling population of the cultivated potato. Amer. Potato Jour. 35: 642.
5. Dionne, Leo A. 1958. 2,4-Dichlorophenoxyacetic acid as an aid to seed production when widely separated *Solanum* species are crossed. Nature 181: 361.
6. ———— and P. B. Spicer. 1958. Staining germinating pollen and pollen tubes. Stain Tech. 33: 15-17.
7. Graham, K. M., J. S. Neiderhauser, and Leopoldo Servin. 1959. Studies on fertility and late blight resistance in *Solanum bulbocastanum* Dun. in Mexico. Can. Jour. Bot. 37: 41-49.
8. Hougas, R. W. and S. J. Peloquin. 1957. A haploid plant of the potato variety Katahdin. Nature 180: 1209-1210.
9. ————, ———— and R. W. Ross. 1958. Haploids of the common potato. Jour. Heredity 49: 103-106.
10. ———— and ————. 1958. The potential of potato haploids in breeding and genetic research. Amer. Potato Jour. 35: 701-707.
11. ———— and ————. 1958. Genetic variation among haploids of the common potato. Amer. Potato Jour. 35: 722 (Abst)
12. King, J. R. and Titus M. Johnston. 1958. Factors affecting Irish potato pollen germination in an artificial environment. Amer. Potato Jour. 35: 689-700.
13. Lee, J. H. and D. C. Cooper. 1958. Seed development following hybridization between diploid *Solanum* species from Mexico, Central and South Ameirca. Amer. Jour. Bot. 45: 104-110.
14. Magoon, M. L., D. C. Cooper and R. W. Hougas. 1958. Cytogenetic studies of some diploid *Solanums*, section Tuberarium. Amer. Jour. Bot. 45: 207-221.
15. ————, ———— and ————. 1958. Cytogenetic studies of South American diploid *Solanum* species section Tuberarium. Amer. Potato Jour. 35: 375-394.
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17. ————, ———— and ————. 1958. Cytogenetic studies of tetraploid hybrids in *Solanum*. Jour. Heredity 49: 170-178.
18. O'Keefe, R. B. and H. O. Werner. 1958. Preliminary report on physiological and genetic studies of heat resistance in *Solanum tuberosum*. Amer. Potato Jour. 35: 724 (Abst).
19. Peloquin, S. J. and R. W. Hougas. 1958. Fertility in two haploids of *Solanum tuberosum*. Science 128: 1340-1341.
20. ———— and ————. 1958. The use of decapitation in interspecific hybridization in *Solanum*. Amer. Potato Jour. 35: 726 (Abst.).
21. Rieman, G. H.,W. J. Hooker, F. A. Krantz and H. O. Werner. 1956. Potato improvement through parental line breeding. Amer. Potato Jour. 33: 319-323.
22. Shark, A. E. 1958. A comparison of microsporogenesis in fertile and sterile potato varieties. Amer. Potato Jour. 35: 726 (Abst).
23. Walker, Ruth I. 1955. Cytological and embryological studies in *Solanum*, section Tuberarium. Bull. Torrey Bot. Club 82: 87-101.

R. W. Hougas K. M. Graham
A. E. Kehr P. Grun
S. J. Peloquin F. I. Lauer
R. Plaisted R. W. Buck
D. A. Young F. L. Haynes
L. A. Dionne, *Chairman*

REPORT OF VARIETY AND NOMENCLATURE COMMITTEE

Abbreviated and Revised Outline

Naming of new varieties — official outline of descriptions to appear in American Potato Journal.

1. Introductory statement
   - A. Originating station or stations and personnel involved.
   - B. Selection of variety name
2. Pedigree discussion
   - A. Characteristics of parental material
   - B. Diagram of pedigree
     Show at least 3 generations except where a named variety appears.
3. Description
   - A. Plants — physiological maturity
     - 1. Growth habit
       - A. Size — Large, medium, small
       - B. Shape — Upright, spreading, decumbent
     - 2. Stems
       - A. Color
         Pigmented or Non-pigmented — distribution
       - B. Wings— Prominent or inconspicuous
       - C. Nodes — Prominent or same size as stem
     - 3. Leaves
       - A. Color
       - B. Pubescence
       - C. Type
         - 1. Closed leaf — Primary leaflets close together and secondary leaflets numerous
         - 2. Open leaf — Primary leaflets widely separated and secondary leaflets few
       - D. Leaflets
         - 1. Terminal leaflets
           - a. Size — Index width to length based on 100 leaves
           - b. Shape — Broadly ovate, ovate, narrowly ovate
             - 1. Apex — Obtuse, acute(accuminate, cuspidate
             - 2. Base — Lobed, truncate, decurrent, symmetrical or asymmetrical
         - 2. Primary leaflets
           - a. Shape
           - b. Number of pairs
           - c. Index width to length based on 400 leaves
         - 3. Secondary leaflets
           - a. Few or many
         - 4. Tertiary leaflets
           - a. Few or many
         - 5. Midribs
           - a. Color
           - b. Pubescence
         - 6. Petioles
           - a. Color
           - b. Pubescence

B. Flowers
  1. Buds
    A. Color
  2. Calyx lobes
    A. Shape
    B. Length
    C. Color
    D. Degree of pubescence
  3. Corolla
    A. Color at time corolla is just fully expanded
    B. Size
  4. Anthers
    A. Color
  5. Pollen
    A. Quantity
    B. Quality

C. Tubers
  1. Shape — Based on 100 tubers of approximately 8 oz. each
    A. Mean length (in cm.)
    B. Mean width (in cm.)
    C. Mean thickness (in cm.)
    D. Indexes
      1. width to length
      2. thickness to length
      3. thickness to width
  2. Skin
    A. Smooth, flaked or netted
    B. Color
      1. Periderm
      2. Cortex
  3. Eyes
    A. Depth
    B. Color
    C. Distribution
  4. Flesh
    A. Color
  5. Sprouts
    A. Color in diffuse light
  6. Maturity
    A. Early — Midseason — Late
    B. Separation from stolons

4. General Characteristics
  A. Observations of plant and tuber characteristics when grown under different environmental conditions with comparison to standard local varieties
    1. Disease resistance
    2. Yield in cwt.
      A. Total
      B. U. S. No. 1
    3. Tuber set
    4. Solids

5. Cooking quality
   A. Chipping quality
6. Storage
7. Market quality

5. Availability of seed stock

O. C. Turnquist J. C. Miller
R. V. Akeley A. G. Tolaas, *Chairman*

REPORT OF EDITORIAL COMMITTEE

Since our last annual meeting, the Editorial Committee has edited and published 61 papers plus the abstracts and the list of foreign research workers and various news notes and announcements. These papers required 370 pages or an average of 37 pages of manuscripts per issue.

The editor greatly appreciated the help generously given by members of the Editorial Committee. Dr. Frank Ross deserves especial credit for the large number of papers that he has carefully edited for the Journal.

We now have 31 papers on hand which is enough for the next six months.

We are desperately in need of papers of a more popular nature for the "News and Reviews" section of the Journal. It is this section that has the greatest appeal and value to the many potato grower members and other non-technically trained readers. We urge you to send in papers of this nature. It may be necessary for the Association to pay authors for such contributions as do some other publications.

I have 11 papers dealing with various types of processed potatoes, fresh potatoes, and the nutritional value of potatoes, for the 1960 Potato Handbook. These will require approximately 45 pages which, with the list of certified seed, buyers' guide, other lists and ads will probably make an 80 page publication.

Your Editorial Committee is trying continuously to improve the value of the Journal and Handbook but we occasionally publish papers of questionable merit. We welcome your criticisms as well as your contributions.

Respectfully Submitted,

Arthur Hawkins Ora Smith
A. Frank Ross R. E. Webb
G. W. Simpson J. C. Campbell, *Chairman*

REPORT OF HONORARY LIFE MEMBERSHIP COMMITTEE

A decision was made by the executive committee following the annual meeting of the Potato Association at Bloomington, Indiana, last year that "the Honorary Life Members to be selected in 1959 include technical men only; two from North America and one from Europe."

The total nominations from the technical field for Honorary Life Membership in 1959 were 18. Sixteen of these were carried over from 1958 and two were new nominees. Two further nominations were submitted but unfortunately these were received after a second deadline

date for receiving nominations had expired, and the ballot had been prepared and sent out.

There was just one person from the technical field in Europe nominated, hence Dr. George Cockerham of the Potato Virus Disease Investigation Section, Scottish Plant Breeding Station, Pentlandfield, Roslin, Midlothian, Scotland, was elected by acclamation.

The two members from North America elected to receive this honor are:

Dr. D. J. MacLeod, (who up until 3 months ago was officer-in-charge of the Laboratory of Plant Pathology), Canada Department of Agriculture, Research Station, Fredericton, N. B.

and

Mr. N. M. Parks, Head of Potato Section, Genetics and Plant Breeding Research Institute, Canada Department of Agriculture, Central Experimental Farm, Ottawa, Ont.

The Honorary Life Membership Committee wishes to submit the following suggestions to the Executive Committee and members of the Potato Association of America:

1. That in the future no nominations be carried over from one year to the next, and (B) that the nominator must provide a biographical sketch of the one whom he nominates.
2. That a new certificate of Honorary Life Membership in The Potato Association of America be developed to include an official crest and the official stamp of the Association and be signed by the President and Secretary.
3. That the method of balloting for election to Honorary Life Membership in The Potato Association of America be published in the Journal in addition to the list of committee members.
4. On behalf of succeeding Honorary Life Membership Committees, the present committee wishes to make the following appeal to members of the Electoral Board:

   First — When you receive the request from the chairman of this Committee for nominations for Honorary Life Membership in our Association, please send in your nominations promptly,

   Second — When you receive the ballot, please mark it indicating your preference, in accordance with the example given in the letter which accompanies the ballot.

   It is on the basis of preference that the ballots are marked and Honorary Life Members chosen. If a ballot is not marked in order of preference it has to be considered as a spoiled ballot.

N. M. Parks, *Chairman*

REPORT OF THE POTATO UTILIZATION COMMITTEE

The series of National Potato Utilization Conferences was continued, with the tenth meeting being held at Idaho Falls, Idaho, July 20-22, 1959. Six of the eight members of our Potato Utilization Committee attended, and several other officers and members of our Association were also in attendance. The program of this meeting in Idaho was made up

of talks on marketing, nutritive value of potatoes, food additives, processing topics, the "Blackspot" problem, and research summaries of work at the Quartermaster Corps Food and Container Institute, at the University of Maine, University of Idaho, Michigan State University, Cornell University and from various divisions of the United States Department of Agriculture. At the close of the Idaho meeting, the conferees decided to accept the invitation of the Florida Fruit and Vegetable Association to hold the next National Potato Utilization Conference in Florida in the Spring of 1961.

Research and commercial developments in potato processing continued to proceed at favorable levels during the past year. The most spectacular growth in any single type of product was in dehydrated mashed potatoes. Dehydrated potato flakes were first produced commercially in January 1958. Eight companies having an estimated capacity of 25 million pounds of flakes per year are now operating in the principal potato producing areas. Some of these plants are at present increasing their capacity as much as 100 per cent. At least two other companies are constructing new plants in Idaho and Minnesota and others are in the planning stage. Research is constantly improving the quality of flakes.

Dehydrated mashed potato powder (granules) was introduced into the U.S. market in 1947 and the production of this item has grown immensely. It is estimated that 70 million pounds of granules were produced from the 1958 crop of potatoes in plants having a total capacity of 75 million pounds. These data may be compared with corresponding figures of 40 and 60 million pounds for the year before. A new granule plant is now under construction and another is being greatly enlarged.

Dehydrated sliced potatoes (dice) are being produced in total quantity approaching 20 million pounds annually. Dice have been used principally in canned hashes and stews. Research is developing dehydrated slices that reconstitute faster in hot water, and this improvement should lead to wider usage.

Potato flour, produced on a modest scale for more than 40 years, now appears to be going through an upswing. Industrial research is showing that potato flour imparts definite advantages in wheat bread. Crackers containing about 20 per cent potato flour are becoming increasingly popular as a snack.

Emerging from a temporary plateau, frozen French fries and other frozen potato products resumed their upward trend with a big increase in demand for the pack from the 1958 crop over that from the 1957 crop. The tonnages of potatoes annually entering the frozen products and dehydration outlets are now about the same. These totals are believed to be approaching 7 million hundredweights of potatoes in each of the frozen and dehydrated products categories, at the current rate of production.

Chips, a long established product and now requiring about 60 per cent of all potatoes entering processing, still show unremitting growth but the percentage rise of this product has been less in recent years than that experienced by dehydrated and frozen products.

Growth in the volume of potatoes used in the canning and pre-peeled potato industries is believed to have been modest during the past year.

A sizable portion of the Nation's potato dehydration and freezing is

carried on in Idaho. Total processing of the Idaho crop in the period from July 1, 1958 to April 30, 1959 was 14.7 million hundredweights (about 40 per cent of the crop), representing a big increase from the 10.5 million hundredweights of the year before. Of this 14.7 million hundredweights, 6.2 million were used for starch and flour and 8.5 million for food products.

Idaho had a record 1958-59 season in starch production, with about 80 million pounds output. Plants in Colorado, Washington, and northern California turned out an estimated total of 23 million pounds of starch during the past season. Maine's total figure for 1958-59 starch producion, while appreciable, is believed to be well below the record for that State set the season before. The 1957-58 season saw Maine's factories produce 138 million pounds of starch (National Potato Council estimate).

The long established outlet for cull potatoes—livestock feeding— continued to take perhaps 5 per cent of the total crop. Most of these potatoes are fed in fresh form.

The book "Potato Processing," by William F. Talburt and Ora Smith appeared in April 1959. This comprehensive text and reference book covers all phases of processing and related subjects.

Manuscripts were prepared during the year for the 1960 Potato Handbook, which is to be published in November on the subject of potato processing.

It is generally conceded that the revolutionary change that the potato industry is undergoing in the switch to a higher consumption of potatoes in processed forms is unmatched in any other commodity. Apparently about 30 per cent of the crop is now being processed in some way. Some predict that this figure may rise to an eventual limit of 60-85 per cent of the crop.

C. E. Cunningham	O. C. Turnquist
D. R. Isleib	E. J. Wheeler
R. L. Sawyer	P. A. Xander
W. C. Sparks	R. H. Treadway, *Chairman*

REPORT OF THE LATE BLIGHT INVESTIGATIONS COMMITTEE

Genetic Variability

The great genetic variability of *Phytophthora infestans* becomes more apparent each year. Canadian workers have isolated races designated as 1, 2, 3, 4, 5; 1, 2, 3, 4, 6; and 1, 2, 3, 4, 5, 6 from juvenile or senescent leaves inoculated with race 1, 2, 3, 4. Given proper selective hosts, any combination of genes for parasitism seems to evolve by processes not necessarily involving sexual structures. Certain race characters, *e. g.* that of race 4, appear spontaneously in single-spore isolates more frequently than do others, although some studies have found races 2 and 3 with almost equal frequency.

Race surveys on R_0 hosts find race 4 predominating in several different parts of the world, again indicating its frequent appearance as a genetic variant and/or its superior ability to survive, once it exists. In Mexico the simple races (0; 1; 2; 3; and 4) predominate on clones without major genes (*Solanum tuberosum*) whereas the more complex races

are detected primarily on derivatives of wild species with corresponding major genes. A similar phenomenon has been observed in *Melampsora lini* Flor. Characters, like the ability to sporulate over a wide temperature range, have been demonstrated for certain isolates, and may account for their survival when one that sporulates over a narrow temperature range only would die out. Whether such characters are linked with genes for specific pathogenicity is not clear.

Lack of virulence in certain races, especially the more complex ones, is probably related to the problem of survival. Such lack of virulence makes difficult the determination of specific identity and the use of such isolates in testing clones for field resistance.

Differentials

Black's clones for race identification continue to be the principal ones used at at least 2 stations, with the addition in Canada of differentials for races 1, 2, 3, 4, 5 and 1, 2, 3, 4, 5, 6. On the other hand some workers, especially those with a large number of seedlings available, change differentials frequently, due primarily to virus infection which is a universal problem.

Seed of *Solanum demissum* lines, presumably true-breeding for gene combinations through gene R_6 is being increased at West Virginia. Dr. Gallegly hopes to be able to distribute some of this seed to interested persons in the fall.

Nomenclature

The discovery of new genes for blight reaction and corresponding races raises several questions. One is that of uniform differentials for the new races and assurance that the same genes and races described by different workers are properly identified. Another is that of nomenclature. Some workers feel that the present system can be expanded to accommodate 6 genes, but that more would make the system too cumbersome. A subcommittee is being appointed to consider this question and to contact workers outside of North America.

Measuring Field Resistance

Quick, inexpensive, and reliable tests for field resistance are still largely unrealized. There is evidence that high peroxidase activity in the leaves indicates high field resistance in *S. tuberosum* but not in *S. demissum* derivatives. This points to the probable complex nature of field resistance, and suggests that only certain aspects of such resistance are measured by peroxidase tests. It is apparent also that clones with field resistance sufficient for use in the United States might be eliminated as susceptible if tested in Mexico.

As a measure of resistance in the field, defoliation estimates by the method of Barrett and Horsfall are in use or are being used in at least 2 stations. Complications due to other defoliating agents are pointed out, but degree of defoliation seems to be the essential basis of comparison, whether the method of Barratt and Horsfall, Large, or others, is used for estimating. Several varieties have been used as standards of comparison, most of which are well know to those testing clones for field resistance. It is suggested that a uniform set of clones for comparison would be desirable, and that such clones should have few or no major genes.

Predicting Blight

Predictions of late blight occurrence and severity are being made in certain places in the southern, midwestern, and northeastern United States. In the South and Midwest probable blight severity is based on temperatures and relative humidities recorded by hygrothermographs placed among potato foliage in the field. A relative humidity above 90 per cent for at least 10 hours at 60 to 80° F. has been found to permit the spread of *P. infestans*. The probable amount of spread is increased with the duration of such conditions and decreased at lower temperatures. With such data from several locations, weekly summaries are compiled and mailed to cooperators, county agents, and others, telling how much the blight probably spread during the period of record, assuming inoculum to be present. On the basis of studies made in cooperation with the United States Weather Bureau it was concluded that synoptic barometric pressure data can be used to predict the blight-favorable micro-meteorological conditions that occur in potato cover.

In the northeastern states initial occurrence of blight is forecast after 10 consecutive days when both rainfall and temperatures are favorable and the current weather forecast is for continued blight-favorable weather. Rainfall is considered favorable when the 10-day total is 1.20 inches or more. Temperature is considered favorable when the 5-day average is less than 78° F. Once blight is established, 10 favorable days are no longer required for it to spread. This information is supplemented by hygrothermograph data. Forecasts are issued from Newark, Delaware and Presque Isle, Maine.

Basic studies on epidemiology include the finding in England that sporangial discharge is stimulated by fluctuating relative humidity. Several instruments to measure the duration of dew on foliage are being tested.

Annual Reports

Most of the committee feel that a better annual summary of progress in late blight research could be prepared by appointing some one or two persons to write such a report, emphasizing different aspects each year, such as genetics of the pathogen, resistance, epidemiology, *etc*. Such reports would be published by the writer as sole author, and the activities of the committee could be summarized in a shorter report.

Late Blight Investigations Committee

R. Bonde
M. E. Gallegly
K. Graham
W. R. Mills
John Niederhauser
J. R. Wallin
Carl J. Eide, *Chairman*

THE INDIAN POTATO JOURNAL

The Indian Council of Agricultural Research recently published the first issue of "The Indian Potato Journal" which is a biannual Journal of the Central Potato Research Institute, Simla (India).

This new publication, edited by Prem Nath, contains sections devoted to new research, news items, and research reviews. The first issue features an article on the present potato research underway in India by Dr. Puskarnath, the Director of the Institute.

The subscription rate is $2.00 per year and single copies may be obtained for $1.00.

Copies are available from The Business Manager, Indian Council of Agricultural Research, Queen Victoria Road, New Delhi-2 (India).